



CONTRACT No. N00014-94-C-0210 BETWEEN
the OFFICE OF NAVAL RESEARCH and NEOCERA, INC.

FIFTH MONTHLY PROGRESS REPORT
dated February 23, 1995

1. Introduction

The goal of this SBIR Phase I project is to establish the feasibility of designing a High Temperature Superconductor (HTS) Superconducting QUantum Interference Device (SQUID) microscope in order to detect defects, and verify customizations and repairs in MCM substrates. The overall goal of this SBIR program is to market an HTS SQUID microscope dedicated to the inspection of MCM substrates in a manufacturing environment. Neocera and its subcontractor, the Center for Superconductivity Research at the University of Maryland, are working collaboratively in this effort.

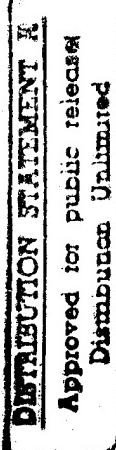
Initial efforts focused on: demonstrating that a room temperature object can be brought sufficiently close to a cryogenically-cooled SQUID sensor to image electrical defects (shorts, opens, voids, particulate contamination, etc.); constructing a room temperature sample stage; and assembling the sensor control and readout electronics. Each of these subtasks have been accomplished.

The secondary effort focused on assembling, testing, and debugging the prototype SQUID microscope, with a cryocooled sensor and a room temperature sample stage. During this period, each of these subtasks were accomplished.

At this time, a fully operational prototype HTS SQUID microscope capable of examining room temperature samples is undergoing functional testing. Figure 1 shows the lower portion of the apparatus, including the room temperature sample scanning stage, sensor extension cryostat, and cryogen resevoir. Nearly all of our Phase I objectives have been achieved or exceeded.

2. Initial results obtained with the prototype

The system has been kept cold since the second week of the reporting period. During this time, numerous images of simple test samples have been obtained. The images presented below are all raw and unprocessed. The SQUID electronics have not yet been optimized to obtain the best quality images. Rather, all the main techniques which are envisioned to be required for MCM inspection are being implemented quickly for demonstration purposes. As a result, some of the images show levels of noise, drift, and other features which can be reduced with a little work.



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1. Reference: DoD Directive 5230.24, Distribution Statements on Technical Documents,
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2. The Defense Technical Information Center received the enclosed report (referenced
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PROGRESS REPORT #5
N00014-94-C-0210
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The cited documents has been reviewed by competent authority and the following distribution statement is
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A

(Statement)

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DEPUTY DIRECTOR
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(Controlling DoD Office Address,
City, State, Zip)

Debra T. Hughes
(Signature & Typed Name)

(Assigning Office)

19 SEP 1995

(Date Statement Assigned)

Figure 2 shows a magnetic image of 50 μA currents flowing in a wire shaped into a meander pattern. The wire lies along the regions where light meets dark, so that their pathway is clearly discernible. The spacing between the wires is about 1 mm, and the x and y scales on all of these images is in units of millimeters. The separation between SQUID and sample was about 200 μm .

Figure 3 shows a magnetic image of the letters UMCP (University of Maryland at College Park) printed on a very fine scale with a laser printer. The letters are about 0.5 mm high. The ink is magnetic, with the light and dark regions in the image corresponding to the north and south poles of different magnetized portions of the ink. From the FWHM of the sharpest features in the image, we deduce a spatial resolution of about 70 μm . This is consistent with the thickness of the sapphire window ($\sim 25 \mu\text{m}$), the separation between sensor and window, and the separation between window and sample.

Figure 4 shows a picture of fields produced by 100 MHz currents flowing in a wire meander. The wires are at the intersection of the light and dark areas. The shading in the image corresponds to the magnitude of the field because a diode detection scheme for sensing the high frequency fields was used.

Figure 5 shows an image of fields produced by a 400 MHz current flowing in a wire loop. The loop axis lies in the plane. By taking a series of such images at progressively higher frequencies, it has been found that clear images can be obtained up to about 800 MHz. Above this frequency, considerable blurring of the images occurs. The blurring is due to resonances in the SrTiO_3 substrate used for the sensor, and is consistent with resonances observed in larger chips. By using a smaller chip with lower dielectric constant, it should be possible to push the operating frequency much higher.

In addition to the images discussed above, eddy current images of patterns etched into copper clad printed circuit boards were obtained. Preliminary measurements of the noise in the SQUID have revealed a flux noise of about $150 \mu\Phi_0/\text{Hz}^{1/2}$ at 1 Hz, corresponding to a field sensitivity of about $300 \text{ pT}/\text{Hz}^{1/2}$ at 1 Hz. This is remarkably low, especially considering that the SQUID is operated without any magnetic shielding, without a shielded room, and is a high- T_c SQUID. The noise is substantially lower at higher frequencies, so that very sensitive eddy current imaging techniques should be possible.

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3. Plans for the Next Period

- Continue in effort to obtain samples of MCM substrates from Mayo Foundation.
- Continue full testing of the prototype HTS SQUID microscope.
- Examine the potential limitations of the microscope.

Steven Green 
P.I., Member of Technical Staff

Date 2/23/95

Neocera, Inc.
335 Paint Branch Drive
College Park, MD 20742-3261

301-314-9937
301-405-9256 (FAX)

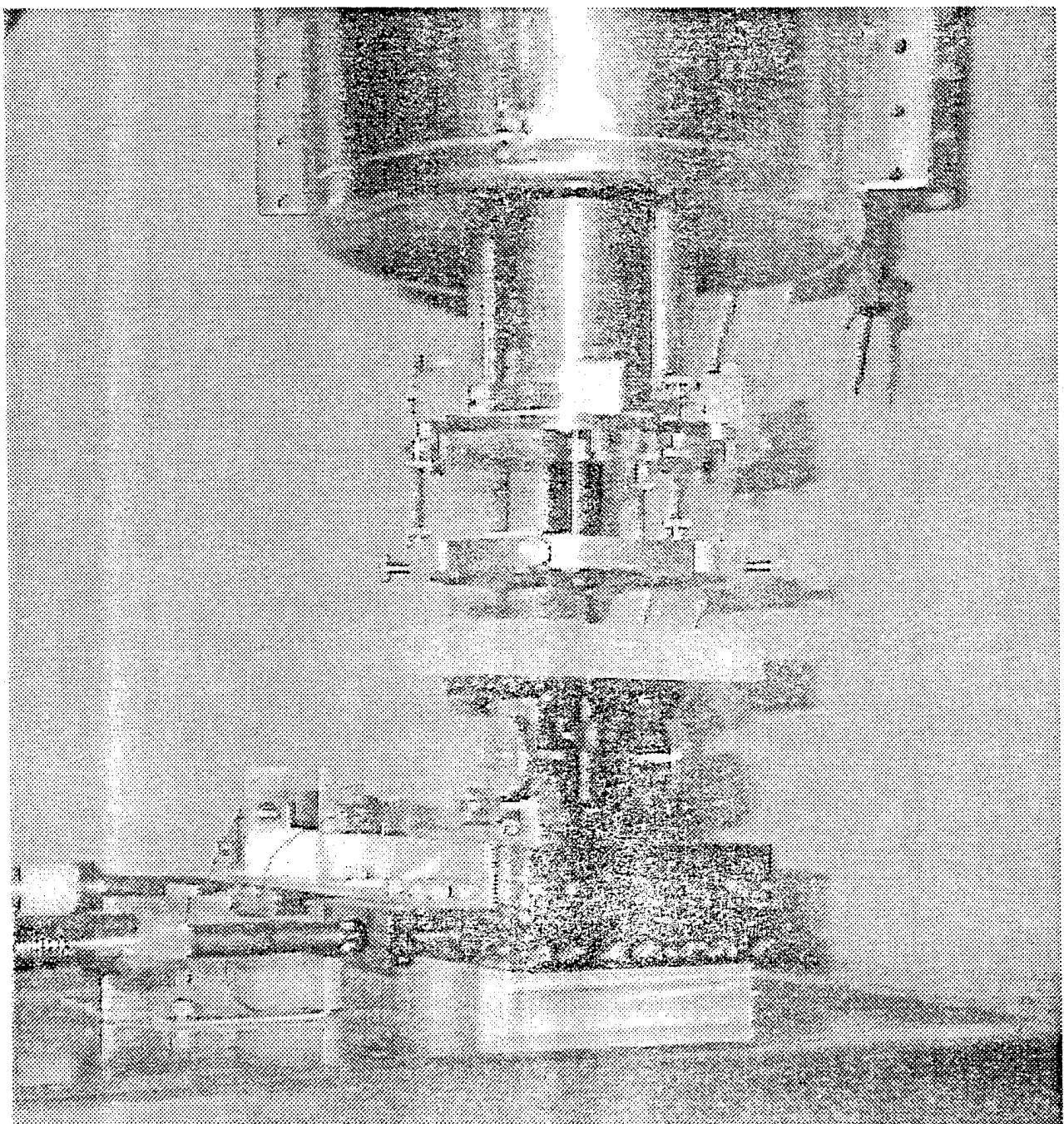


Figure 1. Prototype HTS SQUID microscope with room temperature sample stage.

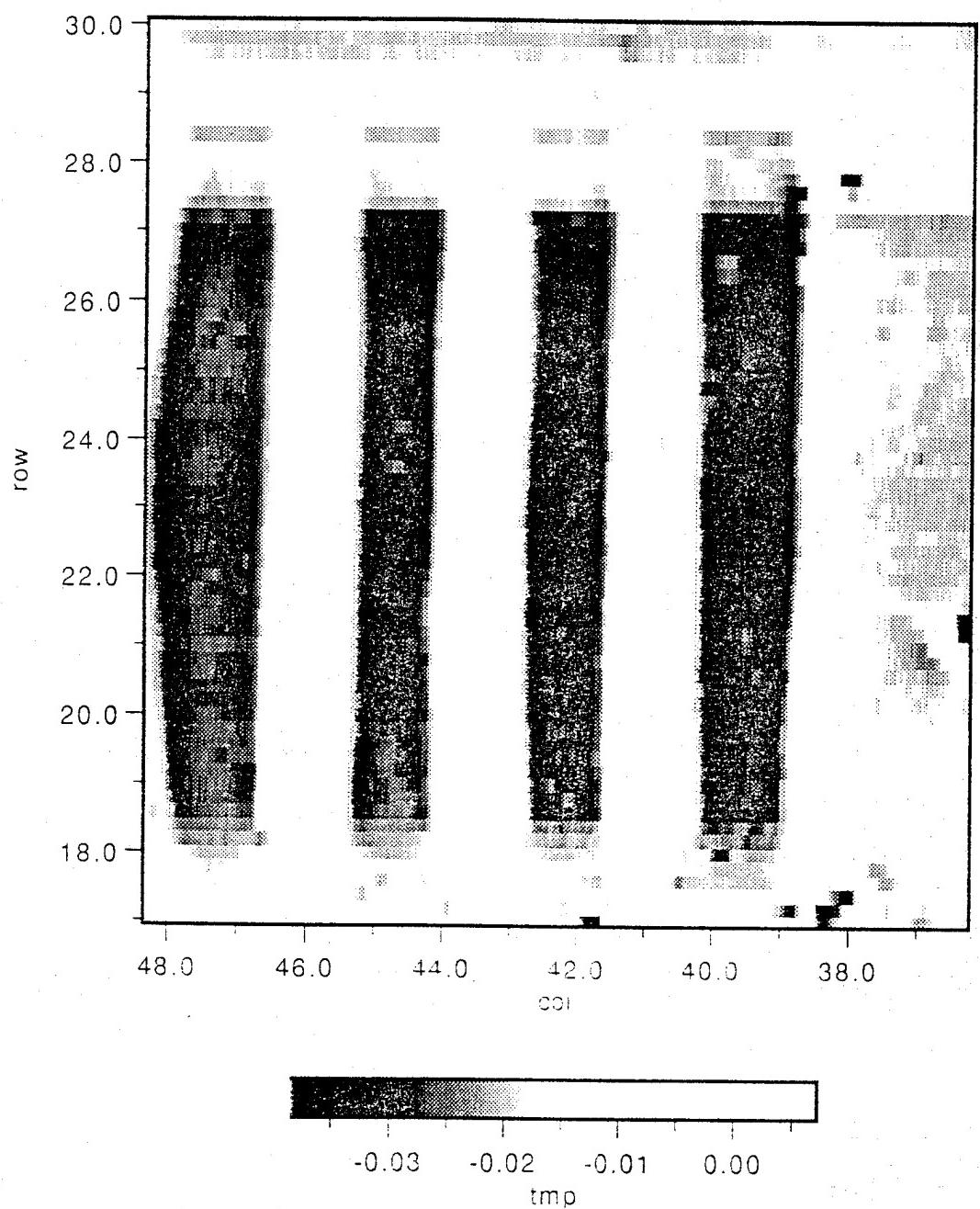


Figure 2. Magnetic fields from meander wire pattern with $50 \mu\text{A}$ dc current.
X and Y scale in mm.

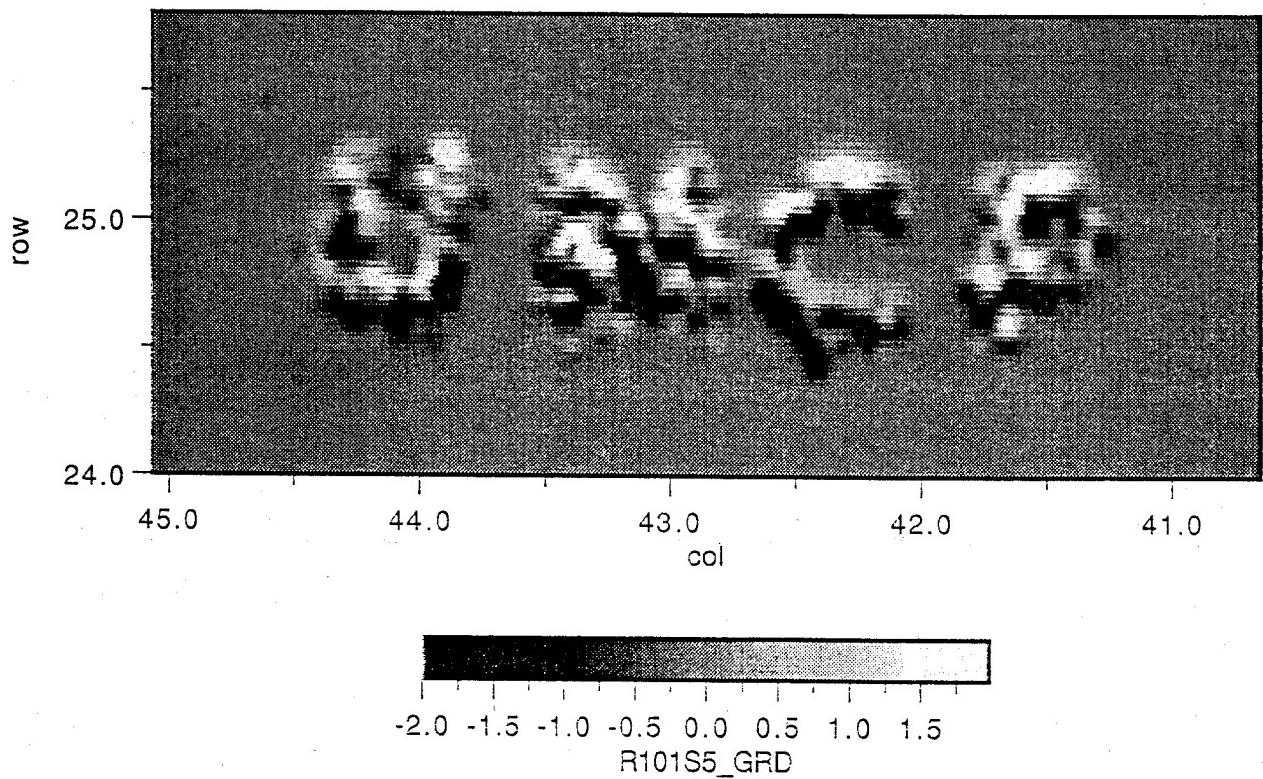


Figure 3. Magnetic image of "UMCP" printed with laser printer ink.
X and Y scale in mm.

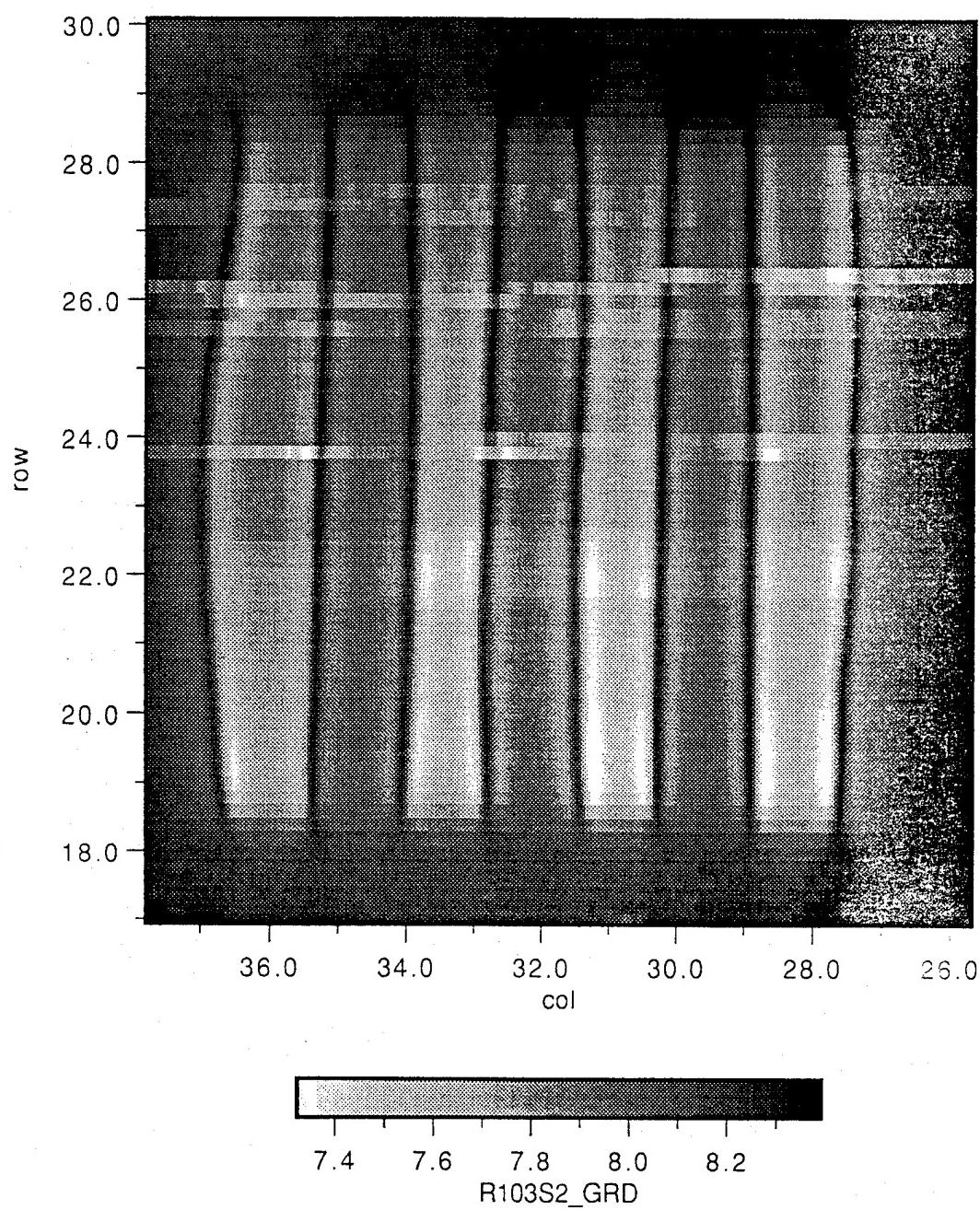


Figure 4. rf image of wire meanders with 100 MHz currents.
X and Y scale in mm.

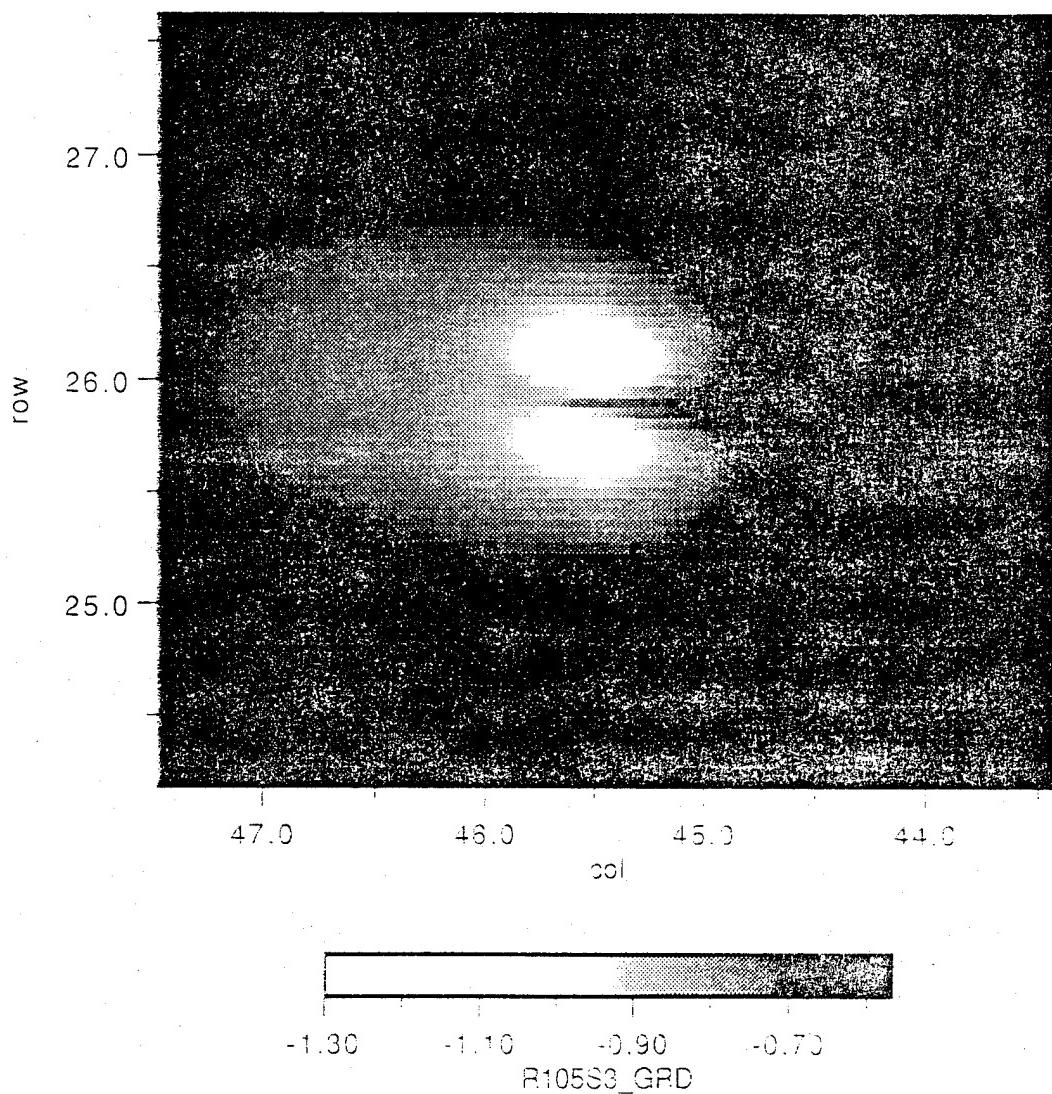


Figure 5. Magnetic image of current dipole loop with 400 MHz currents flowing in the loop.
X and Y scale in mm.